Surf Zone Technology Standoff Delivery Camera Tests and Modeling

Anthony D. Jones
Coastal Systems Station, NSWCDD, Code R13
6703 West Highway 98
Panama City, FL 23407-7001
Phone: (850) 234-4047 Fax: (850) 235-5374 E-mail: JonesAD@ncsc.navy.mil

Joseph W. Foster
Donna Foster
Computer Sciences Corporation
1130 North Eglin Parkway
Shalimar, FL 32579
Phone: (850) 796-3912 Fax: (850) 651-1108 E-mail: fostersail1@yahoo.com

Document #: N0001400WX20025

LONG-TERM GOAL

My long-term goals are to define, analyze, and develop technologies associated with the accuracy of delivery and verticality at impact for long standoff delivery of bombs or other ordnance to be used for clearing obstacles in the surf zone to the craft-landing zone. Additionally, these breaching systems need to be cost effective, delivered from over the horizon, and utilized in-stride with a Marine Expeditionary Force amphibious assault. Specifically we are focusing on developing techniques to terminally guide a sequence of smart munitions to an array of obstacles placed on the beach. The typical target types to be encountered during a mission are hedgehogs, tetrahedrons, concrete blocks, concertina wire, wooden posts, and Jersey barriers.

OBJECTIVES

Potential sensors for a terminal guidance seeker were investigated. The first objective was to capture imagery data of representative surf zone targets using multiple sensors in the visual through long-wave infrared bands throughout a diurnal cycle. The second objective was to capture imagery data of representative target materials at night using a laser illuminator and designator in the short-wave-infrared range. The third objective was to model candidate sensors in order to synthetically generate imagery to be used in the development of techniques to meet the surf zone clearance mission.

APPROACH

Camera Tests

We decided to leverage the camera tests being conducted by the Joint Mine Detection Technology (JMDT) program. The data collection and safety procedures were in accordance with the JMDT Test Plan. The Eglin AFB, Range A22 (Gun/Munitions Test Area) was used for the Diurnal Cycle Test, and the Coastal Systems Station (CSS), Non-Magnetic Test Area was used for the Laser Demonstration.

Eight personnel were involved in the diurnal cycle test, two three-man data collection crews, and a two-man ground crew. Gary Deeds and Abinash Dubey were essential in obtaining the sensors. Gary, Abinash, John Gwyn, Danny Petee, and Chuong Pham assisted in the data collection. Henry Bennett (AIRINC) and Kenneth Tinsley operated the ground equipment and were responsible for safety.

Figure 1. Scissors lift.

A scissors lift (Figure 1) was used for the diurnal cycle test to raise five sensors and a data collection crew to a height of 43 ft in order to image an obstacle/mine field on the beach/surf zone. The scissors lift had a standoff distance of approximately 130 ft.

The five sensors used were:

- Uncooled near/short-wave infrared (SWIR) camera from Sensors Unlimited, Inc.
- Cooled high sensitivity experimental SWIR camera from Sensors Unlimited, Inc.
- Mid-wave infrared (MWIR) to long-wave infrared (LWIR) camera from Inframetrics
- Visible to near infrared (NIR) multispectral camera from Xybion
- Visible black & white camera from PULNiX

The following representative target obstacles (Figure 2) were used for the diurnal cycle test:

- 1 concrete cube (4x4x4 ft)
- 2 steel tetrahedrons
- 2 steel hedgehogs
- 2 wooden log posts (vertically oriented, buried half way)
- 1 coiled roll of concertina wire
- 3 inert anti-tank mines (thermally loaded)

Figure 2. Target Obstacles.

A GPS receiver, compass/inclinometer, and range finder were used to measure location, heading, and distance to the target field. In addition, a Davis GroWeather™ meteorological station was used to supply local environmental data. A generator filtered through an uninterruptible power supply provided power to the camera systems and recording equipment. A light pack was on site for nighttime operations of the lift.

During the laser demonstration the SWIR and experimental SWIR sensors along with two "eye safe" lasers that emit energy at a wavelength of 1.55 µm were used. One laser was an illuminator (wide beam) and the other was a designator (spot beam). Both cameras were mounted on tripods inside a blockhouse, and were used to image surf zone target materials at varying horizontal distances. A GPS receiver, compass, and known distance marks were used for measuring location, heading, and distance to targets.

Modeling

Joseph and Donna Foster used the U. S. Air Forces's multispectral modeling and analysis software, referred to as Irma, to synthetically generate surf zone imagery. The imagery was generated using prospective sensor characteristics, known target and background geometries and characteristics, and munition guidance trajectories to create a sequence of closing images of the surf zone scene. The imagery was then to be compared to actual imagery to validate the models. This data can be used to evaluate the effectiveness of sensor technologies and image processing algorithms for meeting mission requirements.

WORK COMPLETED

Camera Tests

Imagery data of representative surf zone targets was captured using multiple sensors in the visual through LWIR bands throughout a diurnal cycle. Two 12-hour runs were needed to complete a diurnal cycle. Data was collected from approximately 0800-2000 CDT on 16 May 2000 and from 2000-0800 CDT on 17 May 2000. Data from all the sensors were recorded on Hi-8 videotape and encoded with society of motion picture and television engineers' standard vertical interval time code (VITC). VITC was used to time-synchronize each of the different sensors during data collection to Greenwich Mean Time. The imagery was then digitized and given to image processors at CSS for analysis and to Computer Sciences Corp. for synthetic imagery validation.

SWIR and experimental SWIR imagery data of representative target materials was collected during the laser demonstration at night with and without active illumination under no-moon conditions. Data was collected from 1930-2200 CDT on 25 May 2000. The imagery was recorded on Hi-8 videotape. Figure 3 shows a laser spot in the grass at a range of 100 ft.

Figure 3. Laser Spot on Grass.

Modeling

Requirements were first investigated so that a baseline configuration of the surf zone scene could be generated. The established requirements are to terminally guide a sequence of smart munitions to an array of obstacles placed in the surf zone with an accuracy of three meters circular error probable, a trajectory of near vertical, a terminal closing speed of 1000 feet/sec, and a pitch over altitude of 835 meters. Ideally, the surf zone clearance mission will be conducted at pre-dawn hours approaching from the ocean side of the surf zone. A synthetic generation of surf zone targets is shown in Figure 4.

Simulations for varying times of day were conducted in Irma using the direct attack munition affordable seeker (DAMASK) LWIR sensor specifications. These simulations were run in order to determine the sensor's appropriateness for the surf zone mission. Next, the beach scene was modeled using specifications from a SWIR InGaAs-type detector system produced by Sensors Unlimited, Inc. Due to satisfactory field-test results this sensor was used as a baseline for further algorithm development tests.

As it is early in the program, parameters such as sensor resolution and field of view are kept flexible while the number of pixels on target needed to identify a surf zone obstacle, as a 'target-like' structure at the initial mission altitude is being held constant. In order to create more realistic imagery, texturing algorithms were employed to texture the beach background. The texture percent reflectance values were adjusted such that the synthetic images matched well with the real imagery collected during field tests. Finally, closing sequences of images were created and converted into mpeg format. These sequences used predicted trajectory speed and inclination to simulate the terminal munition.

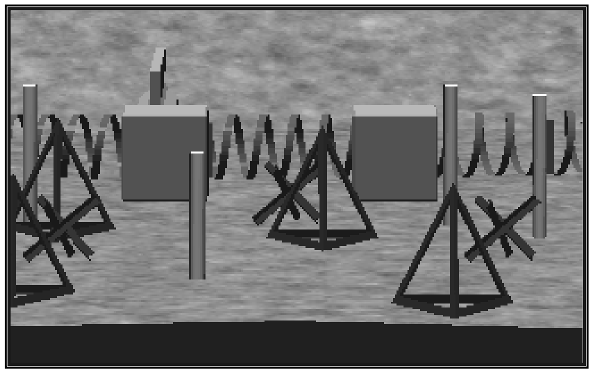

Figure 4. Synthetic Surf Zone Scene

RESULTS

Camera Tests

When comparing the experimental SWIR to the other sensors some interesting observations are made. The SWIR, NIR, and visible B&W cameras all work well during the day but do not image at night without active illumination. Both the experimental SWIR and LWIR are capable of imaging 24 hrs per day without active illumination. During the day, both the SWIR and experimental SWIR produce similar quality images. The MWIR filter was very noisy and was used only during mid-day.

The Sensors Unlimited, Inc. (SUI) experimental SWIR camera performed superbly. The experimental SWIR will image at night under full and no-moon conditions without active illumination, as well as during the day with neutral density filters installed to block out the excess light. When using a laser, the sensor works well. However, if not careful, the laser light can saturate the camera. The sensor can also see through fog or very light clouds as evidenced during the laser demonstration.

The sensor does, however, have several problems. First, the camera needs an automatic gain control to be used for military purposes. Second, the camera has a pronounced image lag (blurring effect) when the camera moves or when something in its field of view moves. Third, there is noticeable random pixel saturation. It was concluded that the second two problems are due to a multiplexer and algorithm compatibility problem in the read out integrated circuit. With some further development these problems can be fixed. If so, this will be an excellent sensor for nighttime use.

A SWIR camera has characteristics similar to that of a visible camera, i.e., the images are collected primarily by the reflectance of light, where as MWIR and LWIR cameras collect imagery primarily by the emittance of heat radiated by a body. Crossover is a problem associated with MWIR and LWIR sensors. Crossover occurs when the temperatures of the background are nearly identical to that of the obstacles – making the obstacles nearly invisible to the sensor. SWIR sensors are not affected by crossover. Mild crossover effects were noticed with the LWIR camera. Figure 5 shows the crossover effect of the LWIR as compared to the Experimental SWIR. In locations where there are rapid and/or dramatic changes in temperature, the crossover effect will be much more pronounced.

Figure 5. Tetrahedron in the water is seen by the Experimental SWIR (L), but not by the LWIR (R). The water acts as a heat sink. Image taken at 0130 CDT.

From a first look at the data, the test team recommends pursuing investigations in the short-wave infrared spectrum. This appears to be a very promising band for the surf zone mission. It has been demonstrated that there is enough useful SWIR energy at night to image targets without active illumination, however active illumination is always an option. SWIR offers good resolution – ideal for the small surf zone targets. In addition, SWIR is not affected by the crossover problem.

Modeling

Results and analysis of the DAMASK simulations indicated that the surf zone obstacles are not resolvable to the degree necessary for image processing algorithms to detect 'target-like' objects. The overall result of the modeling effort is a collection of synthetic images depicting varying target, sensor, and terminal trajectory conditions. These sequences can used to test image processing algorithms for detection and tracking performance. A sample of these results is presented in Figure 6.

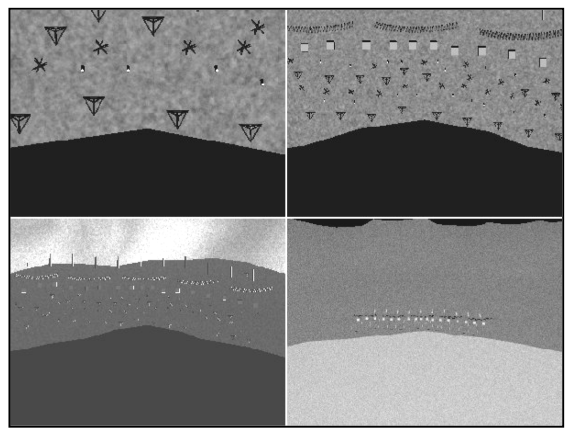

Figure 6. Sample of Synthetic Surf Zone Images.

IMPACT/APPLICATION

The experimental SWIR will be an excellent sensor for nighttime use if the image lag and random pixel saturation problem are fixed. This sensor could be used not only as a seeker, but also as a nighttime aid for special operations and amphibious assault craft. Irma technology has afforded us with multiple images of the same scene and will greatly reduce the costs involved in developing algorithms for the surf zone mission.

TRANSITIONS. None for FY00.

RELATED PROJECTS

This project is directly related to the surf zone image processing efforts concurrently being conducted to develop techniques to guide a series of smart munitions to the target area with a high degree of accuracy. The offsite project most relevant to this project is DAMASK, a 6.2 ONR-funded (Dave Siegel, C351) imaging LWIR seeker being developed by the Naval Air Warfare Center at China Lake.

Howard McCauley, Code 471130D, is the Principal Investigator. Some of the DAMASK hardware, processing, and support algorithms could be adapted for surf zone use.

REFERENCES

J.S. Irving, and M. Schlessinger, 1989. Infrared Technology Fundamentals, Marcel Dekker, Inc.

A.D. Jones and N.A. Levy LongShot™ Hardware-in-loop Simulations, CSS/TR-99/01, (submitted).

PUBLICATIONS

Jones A.D., Surf Zone Technology Standoff Delivery Camera Test Report, CSS/TR-00/15, (submitted).